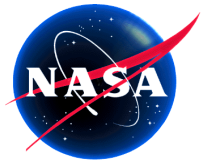

NMP

NEW MILLENNIUM PROGRAM

Technology Flight Validation Planning

for

Future ESE Missions

Fuk Li

Christopher Stevens

Jet Propulsion Laboratory, California Institute of Technology

August 24, 2000

ESE Technology Validation Needs Process

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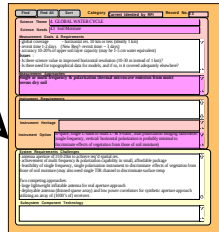
Earth Science Implementation Plan

Earth Science Vision

Baseline Measurement Studies

Technology validation needs identification

- Address key earth science needs
- Strong flight validation rationale
- Capitalize on pipeline investments



ESTO
Earth Science Technology Office

Capability Needs for Science, Application and Technology

Technology Capability Needs

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Flight Validation Rationale

Emerging Technology

Technology Pipeline

- Advanced Technology Initiative
- Instrument Incubator
- Cross Enterprise Technology
- Other Agencies
- Industry

- **Space environment/ effects**
- **Major shift in implementation approach**

Technology Needs Correlated to Measurements

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Technology Development Roadmaps

Measurement Type																
Aerosol Radiative Forcing Research		3					8				1				1	
Carbon Dioxide							9									
Cloud-Radiation Feedback Research		3					8				1	3		2	1	
Cold Land Processes Research					2			1	2					5		
Global Precipitation	1		1			2			6			4		1		4
Global Terrestrial/Oceanic Productivitiy/Advanced Microwave Sounder	6								10			2				
GPS Constellation for Atmospheric Sounding				9								3		7		
Land Cover/Land Use Inventory	3	1	1						4	2						
Ocean Surface Topography												8		2		
Ocean Surface Wind Measurement								3						7		
Soil Moisture and Ocean Salinity Observing						3		6	10			27		4		4
Special Event Imager						1			5		3					
Stratospheric Composition Measurement	1					1	2	3	3	3		4			1	
Surface Water														1		
Time-Dependent Gravity Field Mapping			2				2									
Topography and Surface Change						1	1	3	1					2		
Total Solar Irradiance Monitoring	1					1			3	1					2	1
Tropospheric Chemistry Research							11	1								
Troposperic Wind Sounder		2	1			1	12		5		2					
Vegetation Recovery	1		1			1	4	1	7				3			2
Volcanic Ash and Gas Emission Mapping		1				2			9		6	1			1	

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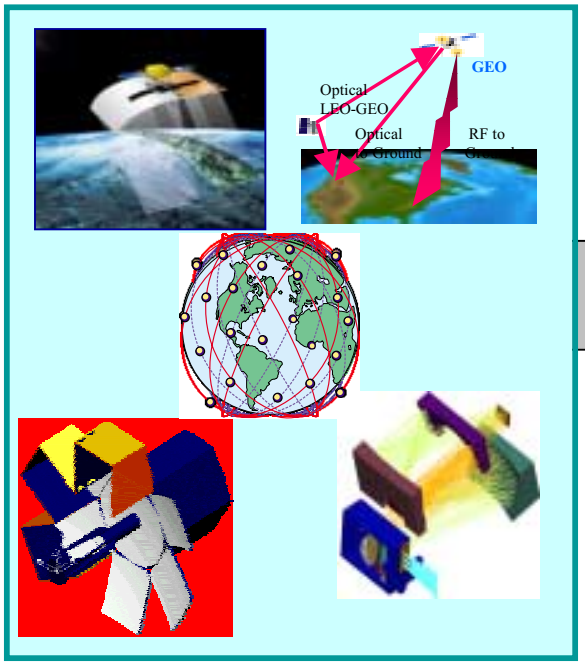
Breakthrough Subsystem Technologies for Flight Validation

- **Ultra-High Data Rate Communications**
- **Large Deployable Antennas**
- **Deployable Telescopes**
- **Distributed Spacecraft Infrastructure**
- **High Performance Spectrometry**

Workshops to Examine Subsystem Technology Validation Needs Supporting Innovative Earth Science Measurements



- Large Aperture Lightweight Inflatable/Deployable/Optics/ Antennas
  - Radiometers -Radars
  - Lidars -Imagers
- Ultra-High Rate Communications/Onboard Processing
  - High spatial/spectral resolution imaging
- Distributed Spacecraft Infrastructure
  - Integrated network observatory
  - Coordinated observations at multiple location/ vantage points.

Workshops to define roadmaps for technology validation needs

- Ultra-High Rate Communications 04/06
- Large Deployable Antennas 04/13
- Deployable Telescopes 04/18
- Distributed Spacecraft Infrastructure 05/01
- High Performance Spectrometry
  - Hyperspectral 05/12
  - Atmospheric 08/25

- Science/technology participants in workshops to identify/define strawman validation experiments
  - co-chaired by scientists/technologists
  - address future science needs
  - technology roadmaps for flight validation in '04/'05
  - attempt to converge on the "right" experiments from science/technology validation perspective

- Initial workshops more heavily attended by NASA participants
  - intend to hold follow-on workshop(s) with broader community participation

Summary of Workshop Key Findings To Date

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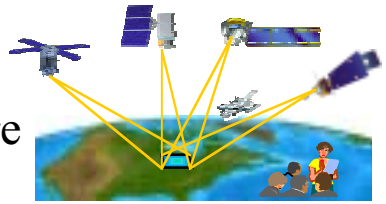
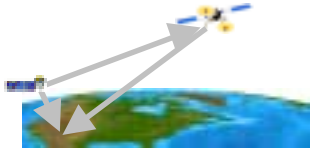
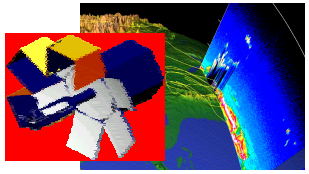
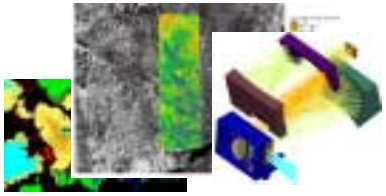
Workshop Title		Key Conclusions	Next Steps
Large, Light-Weight Deployable Antennas		Needed for multiple missions • Soil Moisture, SAR's, Rain Radar • Planar, Cyl, & Reflectors	Trade Studies: • Component vs. subsystem • Antenna type - hybrid? • Identify partners
Intelligent Distributed Spacecraft Infrastructure		Flight validation required: • Spacecraft formation flying command and control – Global Precipitation Measurement • Virtual platforms - system validation needed?	Trade Studies: • Subsystem tests vs. system • Refine user requirements
Ultra-High Data Rate Communications		Multiple needs identified. Optical comm and ultra high rate RF components require flight validation	•Experiment partners •Technology development for W & V-Band, Tera-Hertz
Light-Weight, Deployable UV/Visible/IR Telescopes		Needed for DIAL • Tropospheric chemistry • Deployment, stability need flight validation	•Identify other customers – IR Imaging? •Refine validation needs •Identify flight partners
High Performance Spectroscopy		Multiple customers • Land/Ocean hyperspectral New capabilities needed • S/N, stability, swath width • industry not addressing needs	• Other communities needs/ capabilities? • Spectral range (>2.5µm?) • Leo/GEO S/N, resolution

Integrated Technology Plan To Enable Global Precipitation Measurements

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Objective:

- Provide systematic estimation of global precipitation with three hours or less sampling interval
  - Improved weather forecasting
  - Global water cycle understanding

Technology Challenges:

- Integrated Observatory with autonomous constellation control and operations
- Optimized inter-satellite communications for data handling and downlink
- Large aperture deployable antennas
- Autonomous space/ground internet protocol

Global Precipitation Observation Strategy

Instrument Incubator Program


Imager

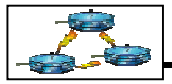

Dual-Freq. Radar Elec.


Drone Radiometers

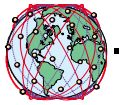
Baseline LEO Science

Enhanced LEO Science/GEO Science

Launch



- **Formation Flying**
- **Inter-satellite communications**
- **Robust routing, adaptive bandwidth**



NMP Validation Flights

Launch


Inflatable Antenna

FY 00 01 02 03 04 05 06 07 08 09 10

Code Y Technology Validation Needs Workshops

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- Results from first five workshops briefed to YS/YO on July 18, 2000 (SAT)
- Organizing "High Performance Atmospheric Spectroscopy" workshop
  - 08/25/00 at LaRC
- Planning broad community participation workshop in late November'00
  - Wider input for technology validation experiment scenarios
  - Explore additional technology subsystem themes
  - Seek participation of YS/YO, and Centers' science and applications leaders
  - Proposed that YS/YO members serve as co-chairs for breakout sessions
- Brief ESE Program Managers on ESE Technology Planning
- Briefing to Code Y in December'00 for Phase A activity planning

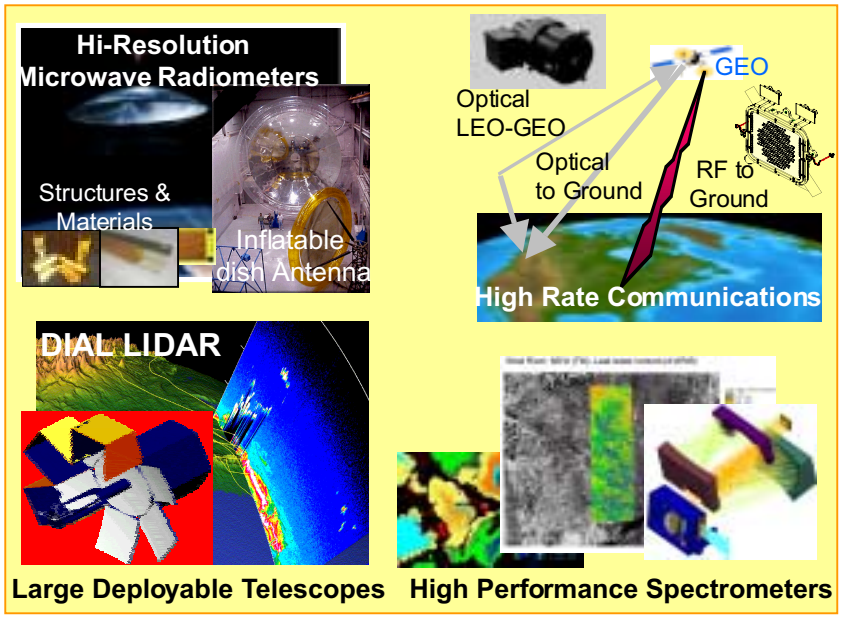
Science, Applications and Technology Community Workshop

Objectives

- Present augmented NMP program structure for subsystem validations to full range of Earth science and applications potential customers and stakeholders
- Further define the technology validation requirements and potential technology solutions derived from the initial mini workshop
- Identify and define additional technology capability areas to broaden the scope of ESE technology planning for ESTO and NMP investments in support of mid-term and far-term measurement needs
- Define set of high payoff subsystem validation candidate technologies whose priority and readiness are consistent with a validation project launch in FY'04/05 timeframe

NMP Dual Paths to Meet ESE Technology Validation Needs

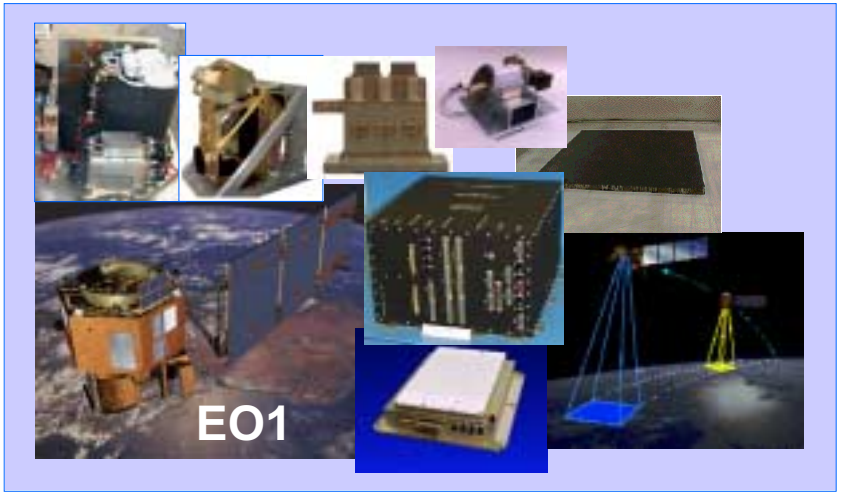
Breakthrough Subsystems



- Breakthrough subsystems that
  - Require flight validation (environment, major implementation shift)
  - Enable critical functions for key/enhanced measurements
  - Yield broad benefits to multiple missions
- Breakthrough subsystems can be tested as stand-alone items without full instruments
  - More cost effective
  - Focus on validating technologies where needed

Augmentation to include validation of breakthrough subsystems

Integrated Measurement System



- Paradigm shift in measurement approach
  - Validation to ensure critical measurement continuity
- Risk mitigation required for operational transition

Sharpen Current NMP Criteria

Potential Programmatic Emphasis for NMP System Validation (fullup measurement systems)

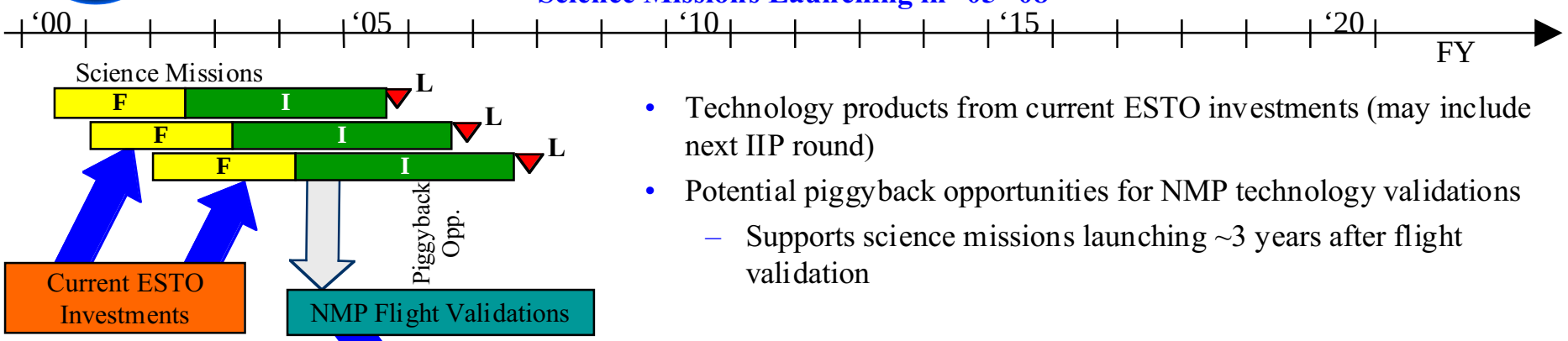
- Recommend that NMP system-level validation (full up measurement systems) focus on:
  - Substantial paradigm shift in measurement approach/fundamental technologies employed
  - Required to ensure critical measurement continuity
  - Risk mitigation for transition to operational missions

Technology/ Measurement Approach	Science Measurement: First Time	Science Measurement: Critical Data Continuity
Low Risk	**ESSP**	**Current Science Missions**
Major Paradigm Shift	**Retire Risk via IIP/other programs**	**NMP**

ESTO/NMP Technology Planning Horizon Synthesis

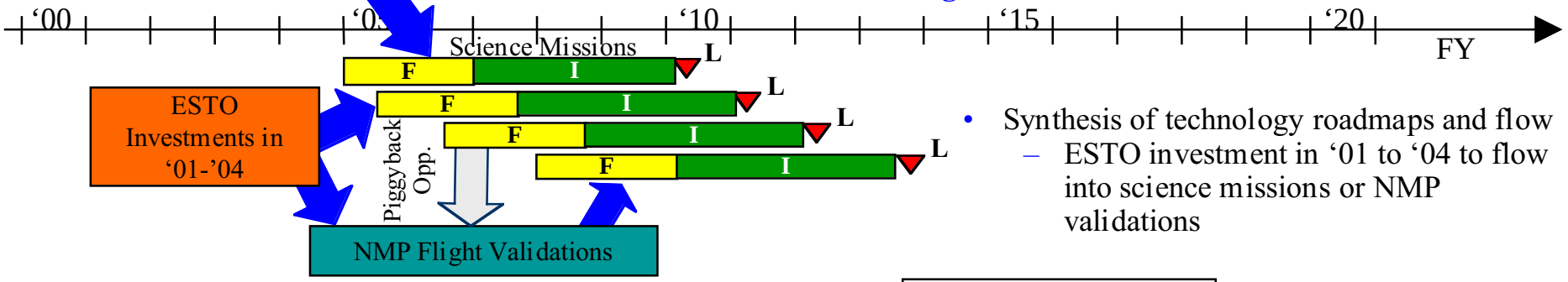
NMP

Science Missions Launching in '05-'08



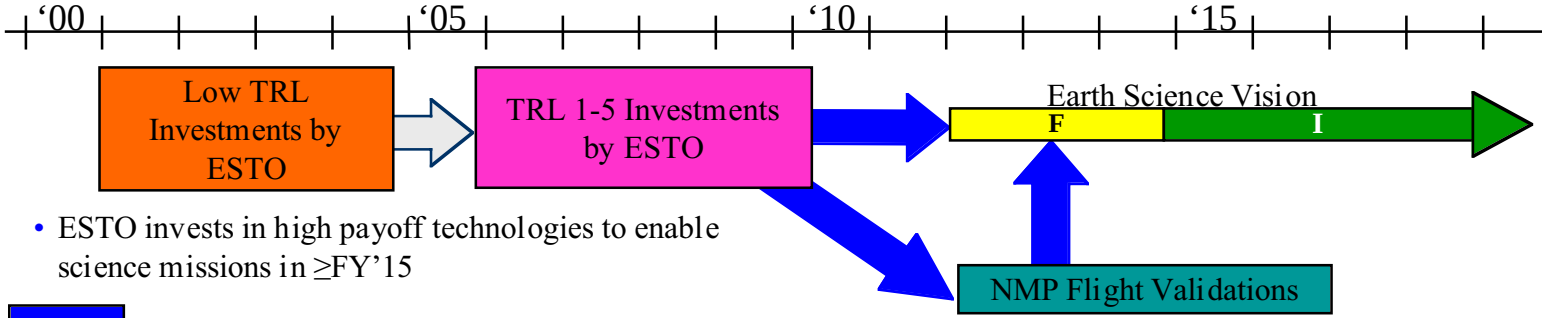
- Technology products from current ESTO investments (may include next IIP round)
- Potential piggyback opportunities for NMP technology validations
  - Supports science missions launching ~3 years after flight validation

Science Missions Launching in '09-'15



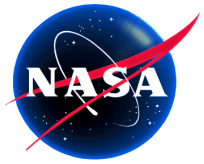
- Synthesis of technology roadmaps and flow
  - ESTO investment in '01 to '04 to flow into science missions or NMP validations

Science Missions Launching ≥'15 ⇨ Earth Science Vision



- ESTO invests in high payoff technologies to enable science missions in ≥FY'15

Technology Infusion



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Back-up

Charts

Flight Validation Justification for Breakthrough Technologies

FACTORS	SUB-FACTORS	EXAMPLE EFFECTS	EXAMPLE JUSTIFICATION
1. SPACE ENVIRONMENT (Ground Test Impossible)	1.1 **Persistent Effects** are steady space/planetary environments acting on the technology.	Zero Gravity, Radiation Effects, Noise Sources, Temperature cycling.	Large, light-weight deployable structures need zero G flight validation because an accurate ground test is impossible.
	1.2 **Transient Effects** are impulse space/planetary environments acting on technology.	Cosmic Rays, Temperature spike, Particle and Fields, Noise, Microphonics	System level faults, such as cosmic-ray induced single-event upsets in integrated circuits. Validation flight needed to confirm software error handlers.
	1.3 **External Interactions** are environments used by the technology to accomplish something.	Cometary Surfaces, Planetary Atmospheres, Solar Wind.	Aeroassist technologies using planetary atmospheres and solar sails using solar wind for propulsion. Both require flight validation to build an experience base and to determine the performance envelope and operating safety margins.
	1.4 **Reliability Hazards** are space/planetary environments that degrade performance.	Micrometeorite, Dust Accumulation, Atomic Oxygen, Radiation Effects.	Micrometeorite, orbital debris, dust accumulation, atomic oxygen, and radiation effects are difficult to predict and simulate.
2. MAJOR IMPLEMENTATION SHIFT (Never Flown Before)	2.1 **Fundamental Change** is a revolutionary way of designing, assembling, fabricating, testing, integrating, or operating.	Revolution in Design Procedures or Operations.	Multifunctional structures invoke new assembly, test and rework procedures that depart from existing practice and require flight validation to verify procedures and demonstrate flight worthiness.
	2.2 **Combined Effects** are complex interactions between advanced technology and different parts of the system or launch vehicle.	Contamination, Noise Sources, Survivability, Ionic Contamination, Launch Debris.	Contamination, deposited by thrusters or other sources, is difficult to predict; thus, flight validation needed to confirm contamination models.

Technology Validation Needs from Science/Applications Plans

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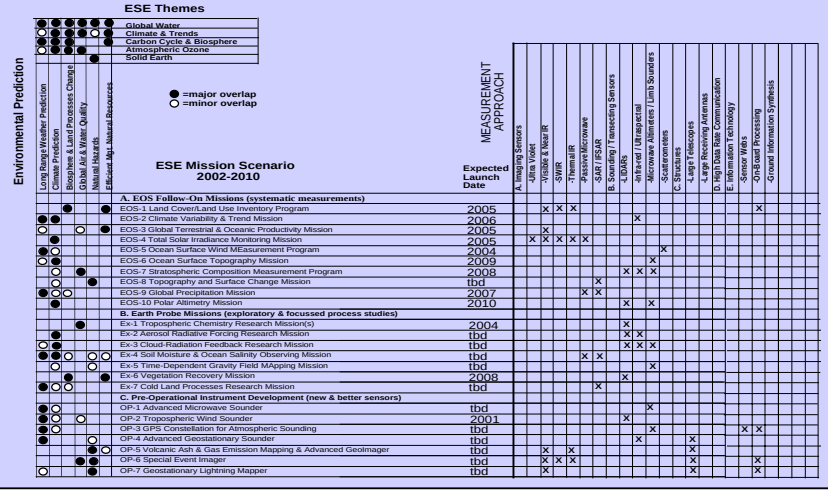
Earth Science Research Plan

Baseline Measurement Studies

Earth Science Technology Needs Analysis

Applications, Commercialization and Education Plan



Emerging Technologies
Potential IIP Flight Validation Candidates

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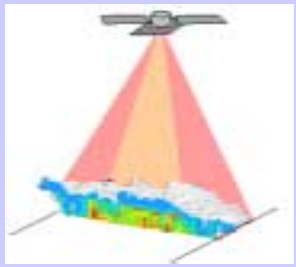
A Second generation Spaceborne Precipitation Radar (PR-2)



Inflatable Antenna

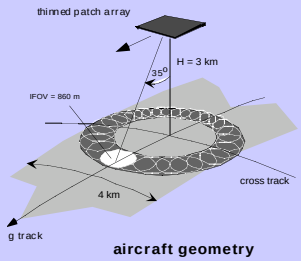
Technology area

5.3 meter dual-frequency(13.6 & 35 GHz) lightweight (100 Kg) inflatable antenna

Flight Validation Rationale

Test the stability and antenna pattern of a large, light weight inflatable structure for 35 GHz frequency, 600 KM swath at 2 Km resolution.

Two Dimensional Synthetic Aperture Radiometer for Microwave Remote Sensing from Space



Large/lightweight Deployable Antenna

Technology area

6X10 meter deployable thin array antenna
Small digital corrolators

Flight Validation Rationale

Validate the thin array antenna concept
Verify structural and thermal stability
Verify two-dimensional aperture synthesis concept

Spaceborne Microwave Instrument for High Resolution Remote Sensing Using a Large Aperture Mesh Antenna

Deployable Mesh Antenna

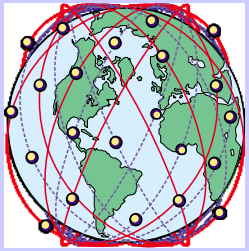
Technology area

6-meter aperture deployable mesh reflector

Flight Validation Rationale

Validate stability of mesh reflector

Active Tropospheric Ozone and Moisture Sounder (ATOMS)



Constellation of Small Satellites

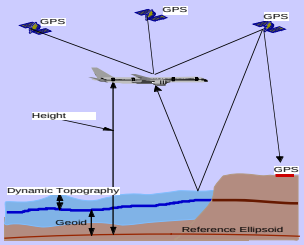
Technology area

10,22, and 183 GHz links for moisture sounding from 0-~20 km 110 and 165 GHz links for ozone sounding from 8km - ~60 km

Flight Validation Rationale

Validate control infrastructure needed for monitoring, controlling, and orbit maintenance of a constellation of small satellites

GPS-Based Oceanographic and Atmospheric Low Earth Orbiting Sensor (GOALS)



Measurement Technique Using Constellation of Satellites

Technology area

Performing surface altimetry using GPS reflections

Flight Validation Rationale

Validate new measurement concept of an on-going measurement